

**Water Resources and Surveying Engineering**

**Development of Bridges Maintenance Management System based  
on Geographic Information System Techniques (Case study: Al-  
Muthanna \ Iraq)**

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**ABSTRACT**

**A** Geographic Information System (GIS) is a computerized database management system for accumulating, storage, retrieval, analysis, and display spatial data. In general, GIS contains two broad categories of information, geo-referenced spatial data and attribute data. Geo-referenced spatial data define objects that have an orientation and relationship in two or three-dimensional space, while attribute data is qualitative data that can be counted for recording and analysis. The main aim of this research is to reveal the role of GIS technology in the enhancement of bridge maintenance management system components such as the output results, and make it more interpretable through dynamic colour coding and more sophisticated visualization techniques than the conventional tabular data format.

To achieve the main objective of this research, two study areas have been chosen: the old construction bridge (Al-Qadisiyah bridge) and the newly constructed bridge (Barboty bridge). Both of them are in Al-Muthanna city \ Iraq. The data collection process was achieved in two stages: the first stage is providing a georeferenced satellite image for each study area for the purpose of producing a two-dimensional map. The second stage includes the field surveying process by total station and level instruments.

GIS have been used to create a comprehensive database (Geodatabase) for both study areas. Geostatistical analysis was carried out in which the settlement areas of both study areas were defined by producing a colour image. The statistical tables for these analyses showed that the highest decline in the elevation reached at Al-Qadisiyah bridge to 19 mm in the middle of the bridge which is coloured as a red area. On the other hand, it was found that the highest decline in the elevation of the Barboty bridge is 16 mm in the last part of steel space which is also coloured as a red area.

**Keywords:** geographic information system, bridges maintenance, geodatabase, satellite Image, geostatistical analysis.

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## تطوير نظام ادارة صيانة الجسور بالاعتماد على تقنيات نظم المعلومات الجغرافية: المثني / العراق كمنطقة دراسة

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### الخلاصة

يعرف نظام المعلومات الجغرافية (GIS) على انه نظام لإدارة قواعد البيانات المحوسبة لتراكم البيانات المكانية وتخزينها واسترجاعها وتحليلها وعرضها. بصورة عامة، يحتوي نظام المعلومات الجغرافية على فئتين واسعتين من المعلومات : البيانات المكانية الجغرافية وبيانات السمة المرجعية. تعرف البيانات المكانية المرجعية جغرافياً بأنها كائنات لها اتجاه وعلاقة في فضاء ثنائي أو ثلاثي الأبعاد ، بينما بيانات السمة هي بيانات نوعية يمكن حسابها للتسجيل والتحليل. يهدف هذا البحث الى الكشف عن دور تقنية GIS في تعزيز مكونات نظام ادارة صيانة الجسور من خلال تمثيل نتائج المخرجات من اختبارات التقييم المرئي والجدول وجعلها أكثر قابلية للتفسير من خلال الترميز الديناميكي للالوان.

لتحقيق الهدف الرئيسي لهذا البحث، تم اختيار منطقتي دراسة في محافظة المثني: جسر قديم الانشاء (جسر القادسية) وجسر حديث الانشاء (جسر بربوتي). ان عملية جمع البيانات كانت على مرحلتين : المرحلة الاولى هي عملية تجهيز صورة فضائية مصححة لكل منطقة من منطقتي الدراسة لغرض انتاج خارطة ثنائية الابعاد ، اما المرحلة الثانية تتضمن المسوحات الحقلية بواسطة جهاز المحطة الكاملة (Total Station) بالاضافة الى جهاز التسوية (level) لقياس البعد الثالث (المنسوب).

تم استخدام نظام المعلومات الجغرافي (GIS) لتكوين قاعدة بيانات شاملة (Geodatabase) لكل طبقة من طبقات كلا منطقتي الدراسة. لقد تم اجراء التحليل الجيو احصائي (Geostatistical analysis) وتم من خلاله معرفة مناطق الهبوط بالمنسوب (الهطول) لكل من منطقتي الدراسة من خلال انتاج صورة ملونة تمتد من اللون الازرق وهي مناطق الامان الى المناطق ذات اللون الاحمر وهي مناطق الخطر. الجداول الاحصائية لهذه التحاليل بينت أن اعلى انخفاض بالمنسوب وصل في جسر القادسية هو 19 ملم في منتصف الجسر. من جهة اخرى، تبين ان اعلى انخفاض بالمنسوب لجسر بربوتي هو 16 ملم في الجزء الاخير من فضاءه الحديدي.

**الكلمات الرئيسية:** نظم المعلومات الجغرافية، صيانة الجسور، قاعدة البيانات الشاملة، صور فضائية، التحليل الجيو احصائي.

### 1. INTRODUCTION

The history of the construction of bridges dates back to 3000 BC in Mesopotamia, used in the Roman era to ease the crossing of the armies, and has always raised the vision of bridges built on the rivers the viewer's surprise. The process of building bridges is the complementary loop of building paved roads and construction of the resulting construction facilitate the process of transport by car through its contribution to reducing the distance and shortening time, effort and expenditure, and to skip many of the natural obstacles and rivers, which are an obstacle to the extension of the roads for it bridge construction requires high engineering experience, and huge equipment and work potential, which is reflected in increased cost of construction, **Johnston, et al., 2001**.

The bridge is a facility that is used to cross from one place to another, with a barrier that may be water or rough terrains. The bridges are composed of reinforced concrete, steel or other constituents such as ropes or wood. The significance of bridge is manifested in the linking of insulated parts such as the banks of rivers and insulated islands. The bridges are particularly important in the wars, as the bridge is a tactical aim that must be endangered at all prices, **Roe and Elliott, 2004**. The bridges can be divided in terms of usage to: cars bridges, railway bridges, pipelines bridges, oil pipelines bridges, and temporary bridges, **Wang, 2006**.

Damage to bridges or lower passageways can be classified as: damage to the concrete walls, damage to the lower parts of the concrete bridges, damage to the concrete by the rust of the reinforcing steel, damage to the chairs, damage to the concrete walls, damage to the concrete walls, damage to the concrete walls, Or damage to the upper part of the concrete bridges, damage to the concrete from iron



rust, damage to collisions with high trucks, damage to expansion joints of bridges etc., and the most significant damage is the passage of heavy duty vehicles carrying more than the specified weight, **Salamak, 2011**. The causes of this damage are due to several reasons, including:

- These bridges are located in the city centers or important transit areas, leading to the crossing of many vehicles on them.
- Absence of supervision and follow-up and weak penalties applied to violators.
- Ease of granting licenses and may be followed by non-specialized sectors.
- Lack of GIS applications in road management facilities and the mechanism of distribution and licensing of restrooms and stations based on data, also geographical areas such as village areas, lengths of roads, places of paintings, sites of gas stations and other statistics such as the density of pedestrians, information restrooms and others.

To overcome these damages four types of maintenance can be followed:

I. Preventive maintenance which means the maintenance work in advance to prevent damage to the components of bridges such as settling the longitudinal and transverse tendencies of the bridge surface to ensure that the water is well discharged through the drainage pipes, cleaning the expansion joint openings with a strong air current, filling the small capillary cracks periodically with cement mixed with water and ensuring the isolation of concrete surfaces etc., **Van Noortwijk, et al., 2004**.

II. Therapeutic maintenance is a total maintenance business that takes place on components of bridge so as to ensure continuity of work such as, treatment of minor cracks and minor volatilization in the asphalt surface layer, repair cracks, breakage and landing at the pier of the bridge etc., **Sandborn, et al., 2007**.

III. Rehabilitation which means a maintenance group that aims to restore the components of the bridge to its design after the exposure of these components to a range of damage caused the reduction of the design or construction capacity of the bridge components such as the treatment of longitudinal and reflective cracks in the surface asphalt layer, dealing with subsidence and erosion in the surface asphalt layer, treatment of volatilization in the asphalt link in the surface asphalt layer, etc., **Powell, 2008**.

IV. Replacement and re-construction which means a business group that aims to re-implement certain components or parts of these components due to exposure to a range of defects that caused damage that reduced the design status or construction capacity of the bridge and made it out of service. This type of maintenance can be represented as replacement of the bridge slab or parts thereof as a result of the corrosion of the tile and its removal from service, replacement of some of the damaged parts of the pavement due to collisions of the vehicles, replacement of the intermediate or intermediate pillars to suit the new design of the bridge etc., **Kamaitis, 2012**.

Geographic Information System (GIS) can be considered as a tool that can be used to develop bridge maintenance management for its ability to represent, process, and analyse all types of bricks on earth using spatial components. GIS data is usually stored can be used to aggregate data in more of a single layer called "shapefile or feature class." These layers can also be combined with other layers of geographic information in a process called data integration. Integrates GIS technology powerful database capabilities with unique visual perspective of a good old-fashioned map. This makes unique GIS between different information gathering systems, **Tomlinson, 2007**. Following are some of previous researches which related to the topic of this research.

**David Moore, et al., 2011** identified in Dubai consisting of bridges with tiled windows and tunnels, air-conditioned foot bridges, long iron bridges. The aim of the Dubai BMMS is to create maintenance movement urgencies and planning details that build sense to the bridges maintenance management engineer and can be practical immediately in the enhancement of acquisition orders to achieve maintenance systems. Dubai's BMMS highlights the usage of practiced bridge engineers for the



condition surveys, as this is deliberated the most important element of any bridge management systems. The condition surveys are based mainly on the rating of faults and usages a system of degree-relevancy urgency. The relevancy evaluation allows the bridges examiner to calculate the faults in footings of their influence on the bridge's structural reliability and on the security of the users. A prioritising system of maintenance management was advanced to accommodate the various kinds of constructions in Dubai. Aurecon Engineering, in companionship with South Africa's Council for Scientific and Industrial Research (CSIR), are improving the ArcGIS-based Dubai BMMS, generating a vastly visual and user-friendly interfaces. Elements of construction prioritising, module corrosion, life-cycle costing and planning employment streamlined calculations that can be promptly interviewed by the users.

**Yuli Yanget, et al., 2012** debated the viability of utilizing GPS and ArcGIS practices in a Bridge Structural Health Monitoring and Management System (BSHMMS). A typical structure of the system depended on the practices of GPS, GIS, Network, and Database is suggested. Based on the progressing of the BSHMMS proto-type, several key practises have been debated, for instance bridge dislodgment measurement in three-dimensional by utilizing GPS, database management of enormous taken data from GPS or other instruments such as total station instruments, management of spatial and healthiness data of bridge or roads and system under GIS system, data handling, visualization and investigation, and the improving practice etc. System running examples display that the suggested techniques and scheme are possible.

## 2. STUDY AREAS

In this research two study areas have been chosen: Al-Qadisiyah and Barboty bridges. Both of them were located in the city of Samawah / Muthana Governorate in Southern Iraq, whose geographic coordinates 32 North and 46 East. Data were collected for each study area in four different periods, the first was in November 2018, the second observation was in February 2019, the third was in May 2019, and the last observation was in August 2019.

### 2.1 Al-Qadisiyah Bridge

Al-Qadisiyah bridge is located in the southwest part of Samawa city. Its located between (523522.786m E, 3458868.649m N) and (523677.602m E, 3458995.62m N), **Directorate of Roads and Bridges in Al-Muthanna, 2018.**

Al-Qadisiyah bridge consists of five concrete spaces; each space is twenty meters long so that the length of the bridge from abutment 1 to abutment 2 will be 100 meters without its approaches. The total length of the bridge is 200 meters, 50 meters on each approach. The width of the bridge is 12 meters. The number of pillars that the bridge stands on is 44 concrete ones; the depth of each pillar is 20 meters. These pillars are distributed where each pier contains 10 pillars with the diameter of 70 centimeters. Additionally, each abutment contains two pillars with 120-centimeter diameter. **Directorate of Roads and Bridges in Al-Muthanna, 2018.**

### 2.2 Barboty Bridge

Barboty bridge is located in the western part of Samawa city. It's laying between (524266.642m E, 3465978.518m N) and (524277.446m E, 3465658.394m N). This bridge is the longest one on the Euphrates, it's connecting Al-Rumaithaa city and Al-Warkaa city together alongside with Samawa city's entrance from the northern side, **Directorate of Roads and Bridges in Muthanna, 2018.**



Barboty bridge consists of 4 concrete and 1 iron spaces. The length of each concrete space is 25 meters, two spaces at the beginning of the bridge and two at end whereas the iron space lies at the middle of the bridge. The length of Barboty bridge is 154 meters long without its approaches, and 319 meters long with its approaches. The width of the bridge is 13.76 meters. The numbers of the pillars that the bridge stands on are 22, each pier contains 3 pillars with 90-centimeter diameter, in addition there are two pillars in each abutment with 140-centimeter diameter, **Directorate of Roads and Bridges in Al-Muthanna, 2018.**

What is worth mentioning, there are many control points which is available around the study areas which can be presented in the **Table 1.**

**Table 1.** Offers the control points which are available about the two study areas.

No. of control point	Easting (m)	Northing (m)	Elevation (m)
Q1	523656.740	3458999.851	7.504
Q2	523568.322	3458883.054	8.025
Q3	523557.758	3458862.538	7.837
B1	524303.980	3465959.043	12.705
B2	524314.635	3465943.356	12.660
B3	524330.251	3465702.256	11.882
B4	524219.411	3465693.089	12.243

### 3. METHODOLOGY AND DATA PROCESSING

#### 3.1 Field Surveying

The field surveying is a process that engineers are looking for required sites to study and gather information about its coordinates, elevations, and satellite images etc. It may normally exceed one hectare or more, often more than a square kilometer area. The field survey may be intrusive or non-intrusive, depending on the needs of the survey team and may also be intense or intense, depending on the type of study required, **Banning, 2002.** In this study, the field surveying is the practice of regulating the terrestrial or 3D-locations of points, distances, and angles among them. These points are typically on the surface of the Earth. Also, they are often utilized to establish boundaries and maps for locations, ownership such as building corners or the surface position of sub-surface features, or other reasons requisite by government or civil law, such as property sales. The steps of the methodology of this research are shown in **Fig. 1.**

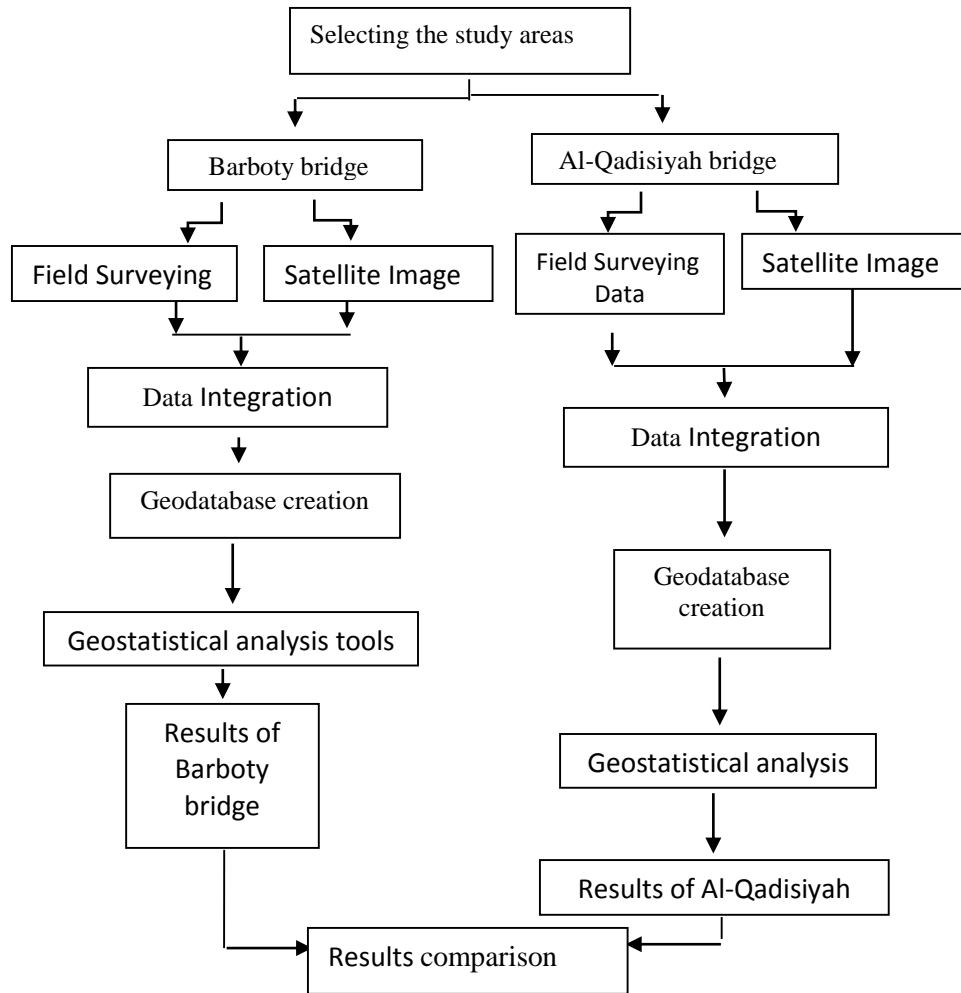


Figure 1. Shows the steps of the methodology of the research.

Field surveying can be described as a purpose of the general position of points on the surface of the Earth. Also, its process of determining vertical and horizontal distance between locations, measuring the slopes between two lines, and governing the directions of lines. Also, along with the real surveys measurement is the geometric calculations. Furthermore, directions, locations, elevations, distances, angles, areas, and volumes are thus determined from the data of the field surveying. Field surveying is depicted graphically by the manufacture of map, cross sections, profiles, and diagrams, **Jishuang**, and **Maohua, 2003**. In this paper, different kinds of instruments and techniques have been used and applied for field surveying, as will be explained in following sections.

### 3.1.1 Instruments Used in This Study

There are two instruments have been used in this study: total station and level. The total station is Nikon-Nivo total station 5.C.  $5'' \pm (3Mm + 2PPM)$ . One advantage of this instrument is that the collected data can be fully converted form the instrument to computer which can be directly used through softwares such as GIS or AutoCAD. The data collected by this kind of instrument can be saved in many formats such as txt, pdf, xps, xml etc.

While the other instrument used in this study is the level Topcon instrument. The Topcon AT-B4 level instrument is a new standard to measure the elevations which is used in surveying, civil engineering, and construction applications. One of its characteristics, the instrument is against the rainwater. The Topcon AT-B4 speedily elevations the line of sight with its excellently tuned magnetic waves system. This instrument features are: 24X magnification, Self-levelling, Sighting Guide, Ultra short 20 cm focusing, Horizontal circle for measurement, magnetic damping, Approximate Range-250 feet, **Gama, et al., 2016.**

### 3.1.2 Software Used in This Study

There are two softwares have been used in this study: Sas.Planet and Geographic information system (GIS) software. The need for satellite imagery for two study areas, in addition to the process of representation and analysis of this data, was the reason for the usage of Sas.Planet and GIS software. Sas.Planet software is one of the most important software which designed for showing and downloading the high resolution satellite images and traditional maps acquiesced by such services as Google Maps, Digital Globe, Yahoo Maps, Yandex Maps, iPhone maps, Virtual Earth, Open Street Map, Genshtab maps, Navitel maps, Bings Maps etc. The downloaded images can be displayed even without the Internet connection, **El-Borsh, et al., 2017.** Satellite images can be downloaded for any part the world by logging into its main interface as shown in **Fig. 2.**



**Figure 2.** Shows a main window of the Sas.Planet software.

The other type of software that used in this research is the ArcGIS10.0 software. The (GIS) software can be used for capturing, analysing, managing, and presenting all appearances of geographically referenced data. A GIS system permits to interpret and analyse the data in conducts that patterns, trends and reveal relationships. This analysis can assist in responding questions and possibly solve difficulties in numerous associated fields such as natural disasters, land-use, and oceanography, **Alfaqih and Hassan, 2013.** Data can be imported to ArcGIS by Add data and add the type of data, such as an image or coordinate files, Base-Map, Geo-Coding, etc.



### 3.2 Data Collection

Data collection is the process of gathering and measuring information on target variables in a specific way and systematic, allowing to each one to answer related queries and estimate results. Data collection is an element of research in all fields of survey, counting social sciences and physical, business, business, and engineering as well. There are many methods which are depending on the tools or instruments (e.g. total station or level instrument) in which the data is collected. The focus on ensuring the accurate collection makes the results that are intended to reach it with high precision, **Lescroel, et al., 2014**. In this paper, each study area was divided into six layers including: the side walk (s), fence (f), border (b), electricity (e), joints (j), and cracks (c).The meteorological process is repeated every 3 months, in 4 different annual seasons, to determine the variation in the levels, the amount of the settlement that occurs for each bridge and its causes and the possible solutions.

Al-Qadisiyah bridge (Q) is the first study area which is observed by total station (Easting and Northing) and level (Elevation). The first two layers were observed are border and fence. Every layer includes 11 stations observed (left, right). The layers are located between (0+50) and (1+50) station. The side walk layer was observed, which includes 21 stations (left, right). These stations start from (0+00) and ends at (2+00). After that, the electricity layer which containing 21 columns for every side. Every electric pole was observed at the base of it.

The joint layer is the fifth layer which was observed by 3 observations (left, right, and center). The number of joints in this study area is six joints which are located in (0+00, 0+20, 0+40, 0+60, 0+80, and 1+00) station. Finally, the cracks layer has been observed at the centre for documentation purposes. All these cracks have been identified with its numbers and discretion. **Table 2.** shows the final shape of each 3-Dimensional point of the Al-Qadisiyah bridge layers.

**Table 2.** presents the final shape of each 3-Dimensional point of the Al-Qadisiyah bridge layers.

station	Easting (m)	Northing (m)	Elevation (m)
0+50	523560.590	3458901.765	9.327
0+70	523575.394	3458915.132	9.485
0+90	523595.506	3458922.513	9.631
1+10	523610.311	3458935.880	9.612
1+30	523625.115	3458949.245	9.471
1+50	523639.923	3458962.612	9.270

Barboty bridge (B) is the second study area which is observed by total station (Easting and Northing) and level (Elevation). The first two layers were observed are border and side walk. Every layer includes 33 stations observed (left, right). The layers are located between (0+00) and (3+20) station. The fence layer was observed, which includes 32 stations (left, right). These stations start from (0+05) and ends at (3+15) station. After that, the electric poles layer was containing 13 columns. Every electric pole was observed at the base of it.

The joints layer is the fifth layer which was observed by 3 observations (left, right, and center). The number of joints in this study area is six joints which are located in (0+50, 0+75, 1+00, 1+54, 1+79, and 2+04) station. Finally, the cracks layer was observed at the centre for documentation purposes. All these cracks have been identified with its numbers and discretion. **Table 3.** shows the time period, date, and the temperature of the observations period. **Table 4.** shows the final shape of each 3-Dimensional point of the Barboty bridge layers.





Table 3. Shows the time, date, and the temperature of the observations period.

No. of Observation	Time of observations	Date of observations	Temperature of observations
1 <sup>st</sup> observation	7:30 am - 11:30 am	3/11/2017 - 12/11/2017	26 C°
2 <sup>nd</sup> observation	8:00 am - 12:30pm	5/2/2018 - 13/2/2018	14 C°
3 <sup>rd</sup> observation	7:00 am - 11:30 am	3/5/2018 - 12/5/2018	35 C°
4 <sup>th</sup> observation	6:00 am – 11:00 am	6/8/2018- 15/8/2018	47 C°

Table 4. Shows the final shape of each 3-Dimensional point of the Barboty bridge layers.

station	Easting (m)	Northing (m)	Elevation (m)
0+00	524266.642	3465978.518	13.221
0+00	524282.986	3465978.408	13.219
0+10	524266.514	3465968.518	13.343
0+10	524282.858	3465968.408	13.355
0+20	524266.387	3465958.519	13.448
0+20	524282.730	3465958.409	13.461
0+30	524266.260	3465948.518	13.521
0+30	524282.603	3465948.410	13.519
0+40	524266.132	3465938.52	13.644

### 3.3 Geostatistical Analysis Tools

The analysis process of data collection is very fundamental in the GIS system, and may be need to specific systems to perform many functions. The most important processes are: cartographic functions, query and research, as well as the measuring of the parameters and phenomena tools such as the near, buffer, and the geostatistical analyst tools. Geostatistical analyst tools are containing Interpolation tool, sampling network design tool, simulation tool, utilities tool, and working with geostatistical layers tool. Each of these tools is contains several methods to carry out the analysis. This study used interpolation tool, to analyse the data collected.

Interpolation tool is the process of obtaining a value for a mutable of awareness at a location where the data has not been detected, utilizing data from locations where the data has been gathered. There are many methods for interpolation tool, which they reduction into two general categories: deterministic and probabilistic. Deterministic methods utilize the pre-defined functions of the distance among observation locations and the location for which interpolation tool is prerequisite (such as, Inverse Distance Interpolation or Moving Window Kriging). This section will briefly discuss the geostatistical interpolation tool, then offers some of details about the Inverse Distance Weighted IDW model which realized in ArcGIS 10.1 Geostatistical Analyst, **Kumar, et al., 2007**.

Inverse Distance Weighted (IDW) is the method that should be utilized when the set of points is dense sufficient to take the extent of local surface difference wanted for analyst. IDW regulates cell values utilizing a linear weighted mixture set of sample opinions. The weight allocated is a function of the



distance of the input points from the output cells location. The larger the distance, the fewer influence the cell has on the output values, **Childs 2004**. The general formula of IDW is:

$$\hat{Z}(s_0) = \sum_{i=1}^N \lambda_i Z(s_i) \tag{1}$$

Where:

$\hat{Z}(s_0)$  is the value we are trying to predict for location  $s_0$ .

$N$  is the number of measured sample points surrounding the prediction location that will be used in the prediction.

$\lambda_i$  is the weights assigned to each measured point that we are going to use. (These weights will decrease with distance).

$Z(s_i)$  is the observed value at the location  $s_i$ . The formula to determine the weights is the following:

$$\lambda_i = d_{i0}^{-p} / \sum_{i=1}^N d_{i0}^{-p} \tag{2}$$

$$\sum_{i=1}^N \lambda_i = 1 \tag{3}$$

As the distance becomes larger, the weight is reduced by a factor of  $p$ . The quantity  $d_{i0}$  is the distance between the prediction location,  $s_0$ , and each of the measured locations,  $s_i$ .

The power parameter  $p$  influences the weight of the measured location's values on the prediction location's values; that is, as the distance increases between the measured sample locations and the prediction location.

### 3.4 Geodatabase Creation

The geodatabase offers a common framework for geographic information. This framework can be used to define a wide variety of different users or application specific models. The main tools can be used to create and edit geodatabases are found in ArcCatalog and ArcMap. There are many tools in ArcCatalog for creating and modifying the geodatabase schema, while ArcMap has tools for editing and analysing the contents of the geodatabase, **Balovnev, et al., 2004**.

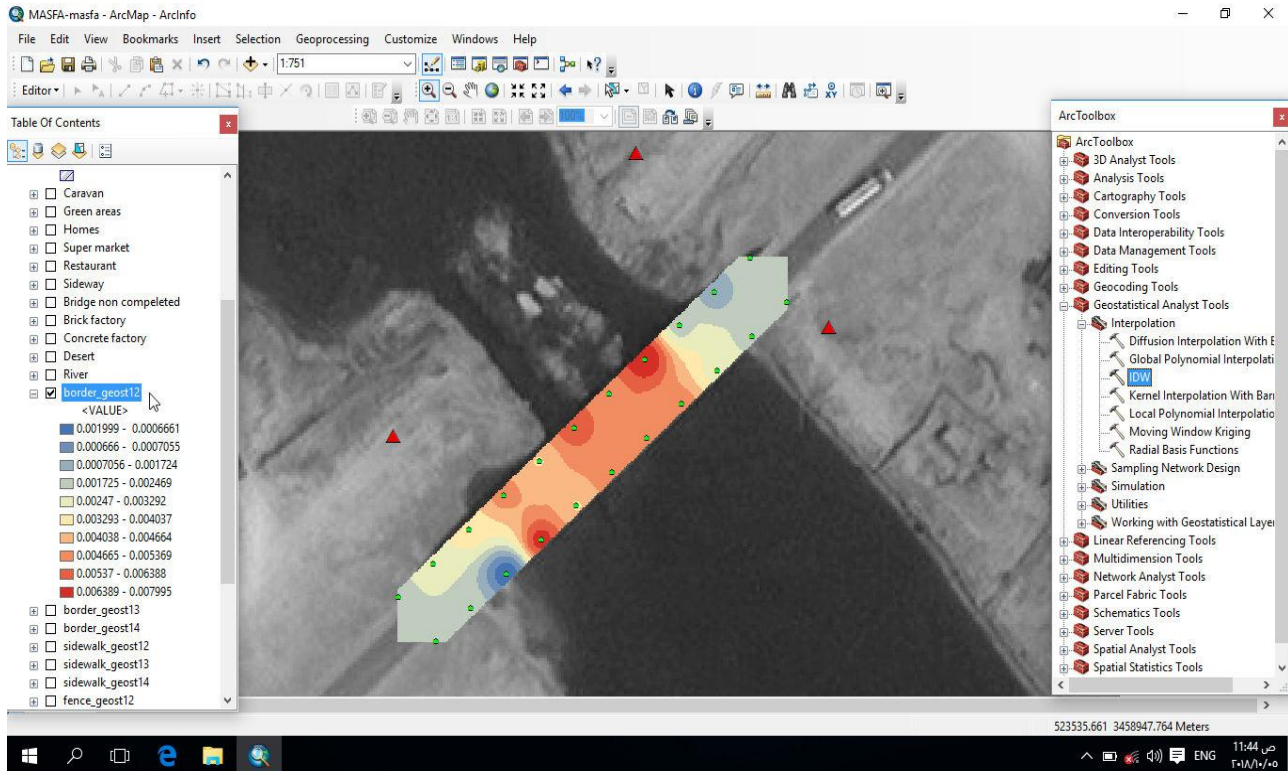
The files which usually added into GIS interface are text file, and for creating databases they should be converted into geodatabase through the many steps. It's worth mentioning, that text file or shapefile can be converted to the feature class or file personal class.

## 4. RESULTS AND DISCUSSIONS

This section presents the analysis of the results for the data collected for each study area by field surveying instruments. The main part of these results based on geostatistical analyst tools with interpolation (by IDW method) which is identified in previews section.

### 4.1 Results of Geostatistical Analysis

The geostatistical analysis was performed for each layer of Al- Qadisiyah bridge and Barboty bridge by interpolation tool using IDW method as explained in section three. This method was applied to compare observation one, two, three, and four for each layer of both study areas. One of the outputs of this analysis to compare observation one and two for border layer of Al-Qadisiyah bridge can be seen in **Fig. 3** and **Table 5**.



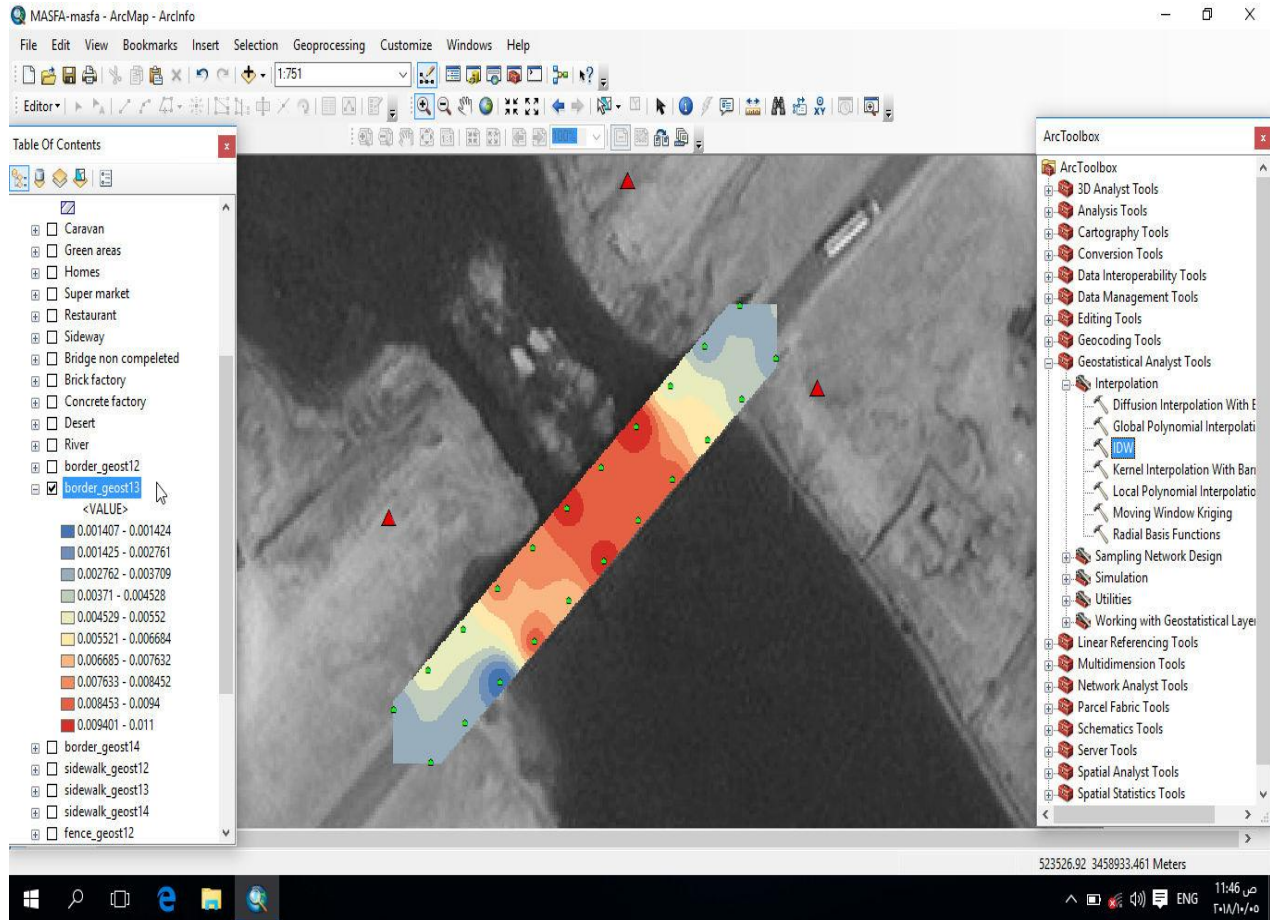
**Figure 3.** Shows the geostatistical analysis for the border layer of Al-Qadisiyah bridge (between observation 1 and 2).

**Table 5.** Shows the descriptive statistics for the differences between observation 1 and 2 for the border layer.

Observation	Minimum (m)	Mean (m)	Maximum (m)	Standard Deviation (m)
1-2	0.001	0.003	0.007	0.001

In **Fig. 5** the blue colour refers to the areas where there is a decline in the elevation which is ranging from 0 to 2 mm. The colour gradient extending from dark blue to yellow, represents a very small change in the elevation which is not exceeding 1 mm. This change can be noticed at the beginning of the northern and southern bridge approaches. The yellow areas refer to the decline in the elevation which is ranging from 3 mm to 5 mm. The color gradient extends from dark yellow to red, represents the highest change in the elevation between these observations, which is exceeded 4 mm. This change happened at the middle space of the bridge and the spacecraft adjacent to it. In addition, the red areas are the most settlement areas which are ranging from 6 to 8 mm.

**Table 5.** showed that the lowest change in the elevation is equal zero, especially at the beginning of the northern and southern bridge approaches on the border layer, but the highest change in the elevation was 7 mm at the middle of the bridge in the same layer. The third observation of Al-Qadisiyah bridge has been achieved after six months of the first observation. The IDW method was also applied to compare the observation one and three. The output of this analysis for border layer of Al-Qadisiyah bridge which can be seen in **Fig. 4** and **Table 6**.



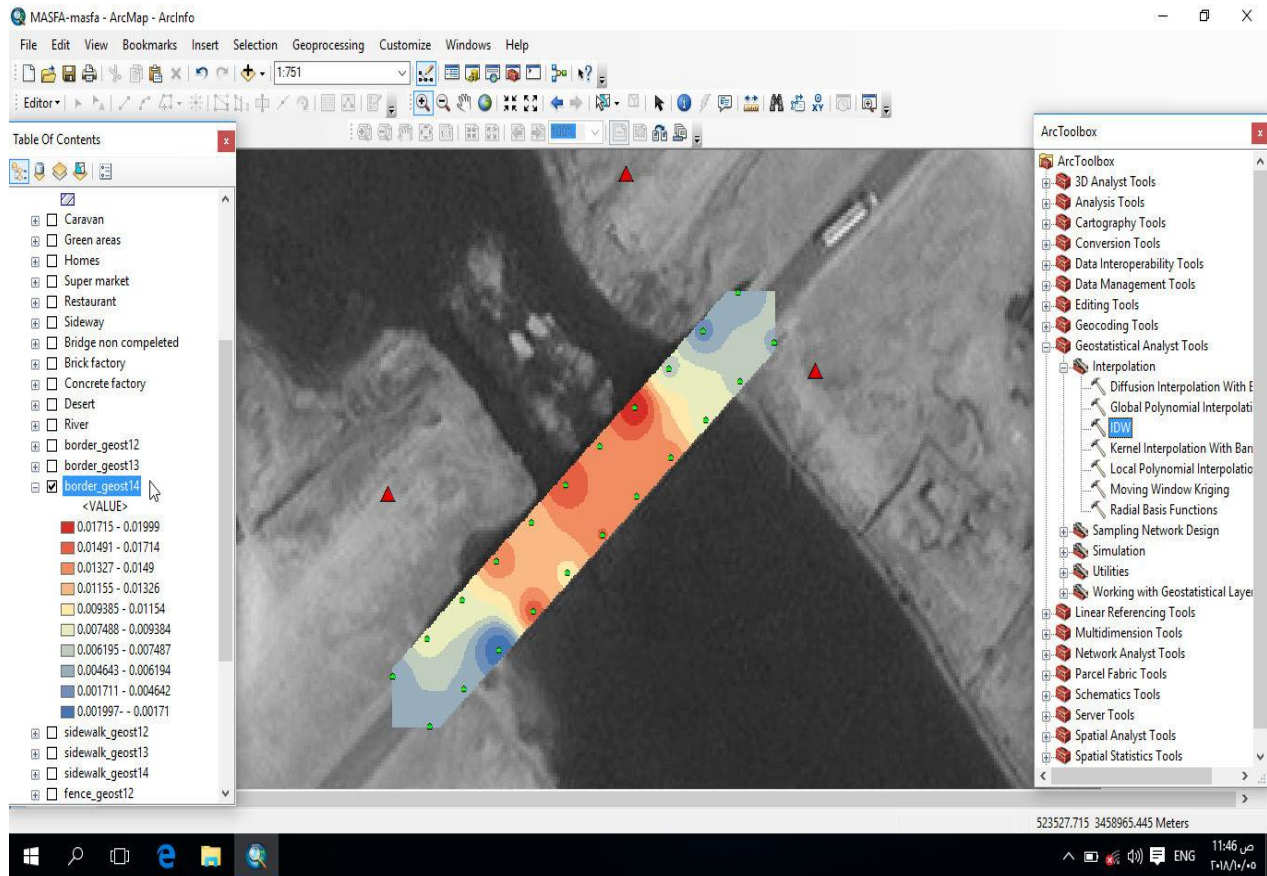
**Figure 4.** Shows the geostatistical analysis for the border layer of Al-Qadisiyah bridge (between observation 1 and 3).

**Table 6.** Shows the descriptive statistics for the differences between observation 1 and 3 for the border layer.

Observation	Minimum (m)	Mean (m)	Maximum (m)	Standard Deviation (m)
1-3	0.000	0.006	0.011	0.003

Through the geostatistical analyses, (Fig. 6) between the first observation and the third for border layer, the blue colour refers to the areas where there is a decline in the elevation which is ranging from 0 to 3 mm. The colour gradient extending from dark blue to yellow, represents a very small change in the elevation which is not exceeding 2 mm. This change can be noticed at the beginning of the northern and southern bridge approaches. The yellow areas refer to the decline in the elevation which is ranging from 5 to 7 mm. The color gradient extends from dark yellow to red, represents the highest change in the elevation between these observations, which is exceeded 6 mm. This change happened at the middle space of the bridge and the spacecraft adjacent to it. In addition, the red areas are the most settlement areas which are ranging from 9 to 12 mm.

**Table 6.** showed that the lowest change in the elevation is equal to zero, especially at the beginning of the northern and southern bridge approaches on the border layer, but the highest change in the elevation was 11 mm at the middle of the bridge in the same layer. The fourth observation of Al-Qadisiyah bridge has been achieved after nine months of the first observation. The IDW method was also applied to compare the observation one and four. The output of this analysis can be seen in **Fig. 5** and **Table 7**.



**Figure 5.** Shows the geostatistical analysis for the border layer of Al-Qadisiyah bridge (between observation 1 and 4).

**Table 7.** Shows the descriptive statistics for the differences between observation 1 and 4 for the border layer.

Observation	Minimum (m)	Mean (m)	Maximum (m)	Standard Deviation (m)
1-4	0.002	0.011	0.019	0.004

Through the geostatistical analyses, (**Fig. 7**) between the first observation and the last for border layer, the blue colour refers to the areas where there is a decline in the elevation which is ranging from 0 to 4 mm. The colour gradient extending from dark blue to yellow, represents a very small change in the elevation which is not exceeding 3 mm. This change can be noticed at the beginning of the northern and southern bridge approaches. The yellow areas refer to the decline in the elevation which is ranging from 9 to 11 mm. The color gradient extends from dark yellow to red, represents the highest change in the elevation between these observations, which is exceeded 10 mm. This change happened at the



middle space of the bridge and the spacecraft adjacent to it. In addition, the red areas are the most settlement areas which are ranging from 15 to 18 mm.

**Table 7.** showed that the lowest change in the elevation is equal to zero, especially at the beginning of the northern and southern bridge approaches on the border layer, but the highest change in the elevation was 19 mm at the middle of the bridge in the same layer.

**4.2 Results of Geodatabase Creation**

The geodatabase of Al-Qadisiyah and Barboty bridges layers includes designing and creating database about information obtained from Directorate of Roads and Bridges in Muthanna and field surveying process. The geodatabase was created using ArcCataloge environment in ArcGIS software. **Table 8.** show the geodatabase of border layer of Al-Qadisiyah bridge as example about these results.

**Table 8.** Presents the geodatabase of border layer of Al-Qadisiyah bridge.

OBJ.	station	X	Y	Z1	Z2	Z3	Z4	$\Delta Z$ 12	$\Delta Z$ 13	$\Delta Z$ 14	Shape *
1	0+50	523559.129	3458903.012	9.613	9.611	9.610	9.608	0.002	0.003	0.005	Point Z
2	0+60	523566.552	3458909.713	9.712	9.709	9.707	9.704	0.003	0.005	0.008	Point Z
3	0+70	523573.974	3458916.415	9.801	9.797	9.796	9.792	0.004	0.005	0.009	Point Z
4	0+80	523581.396	3458923.116	9.921	9.916	9.913	9.906	0.005	0.008	0.015	Point Z
5	0+90	523588.819	3458929.818	10.011	10.01	10.003	9.999	0.004	0.008	0.012	Point Z
6	1+00	523596.241	3458936.519	10.081	10.08	10.071	10.06	0.006	0.010	0.017	Point Z
7	1+10	523603.663	3458943.220	9.921	9.916	9.912	9.907	0.005	0.009	0.014	Point Z
8	1+20	523611.086	3458949.922	9.842	9.834	9.831	9.823	0.008	0.011	0.019	Point Z
9	1+30	523618.508	3458956.623	9.753	9.751	9.748	9.746	0.002	0.005	0.007	Point Z

Attribute of each theme interconnects with the themes once the theme is active as shown above in the tables which involve: station number (sta.), easting (X), northing (Y), elevation of observation one (Z1) elevation of observation two (Z2), elevation of observation three (Z3), elevation of observation four (Z4), difference between first and second elevation (d12), difference between first and third elevation (d13), difference between first and last elevation (d14), and the type of the observation (shape). These geodatabases have been saved and can be managed contrary. Creation compatible geodatabase can save time, effort, and cost for bridge maintenance decision makers.

**5. CONCLUSIONS**

By following the research methodology, several research outcomes have been concluded. The main of these outcomes have been illustrated as follows:

- 1- The outcome of geostatistical analysis showed that, the greatest decline in the elevation of Al-Qadisiyah bridge was 19 mm at the middle of the bridge in the border layer. In contrast, the greatest descent in the elevation was 16 mm at the steel portion of Barboty bridge in the side walk layer. Therefore, it is suggested to carry out other studies for the governorate's bridges such as Al-Rumaitha bridge and Al-Majd bridge. This can help to create compatible geodatabase for the major bridges in Al-Muthanna city.
- 2- The geostatistical analysis found that the greatest decline at the middle space of Al-Qadisiyah bridge was in station (1+10). On the other hand, the geostatistical analysis at the last part of the



steel space of Barboty bridge suffered decline in the elevation at station (2+00). Therefore, it is recommended to build new bridges to avoid the accumulation of heavy vehicles on board of the bridges, which may help to reduce the decline of the elevation of the bridge.

- 3- The steel part of Barboty bridge has shown highly change (decline) in elevation which is equal 16 mm in side walk layer at station (2+00). Therefore, steel part should have more attention and consideration from directorate of roads and bridges in Al-Muthanna city.
- 4- Stringent control on the weight of vehicles coming from the cement factories to the city center should be implemented in order to avoid damage to the bridge's joints and to avoid the changes in the elevation of the bridge.
- 5- The geodatabase which was created in this research can save time and money for the directorate of roads and bridges to identify the problems of bridges, which can take several days or months using traditional methods. Therefore, it is suggested to establish GIS department in all municipalities of the city, and the directorate of roads and bridges to provide database information for the transportation sector.

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